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Description

FAN IMPELLER AND FAN MOTOR

BACKGROUND OF INVENTION

TECHNICAL FIELD

[Para 0001] The present invention relates to cooling-fan motors and impellers that are used in electronic devices and the like. More specifically, the present invention relates to fan motors that must generate high static pressure and ample airflow volume, and to cantilever-type impellers that are used in such fan motors.

DESCRIPTION OF THE RELATED ART

[Para 0002] Fig. 8 is a plan view of a conventional centrifugal fan motor. Fig. 9 is a vertical cross section along the line X_1–O_1–Y_1–Z_1 in Fig. 8. This centrifugal fan motor includes a motor component 104 for generating rotational driving force, an impeller component 101 for generating airflow, and a housing 106. This centrifugal fan motor has a rotational axis O_1 shown in Fig. 8.

[Para 0003] The impeller component 101 is located around the outer periphery of the motor component 104 and includes a lower end wall 102 and blades 103. The lower end wall 102 is an annular plate member located surrounding the motor component 104 at a lower position in the axial direction, and lies in a plane perpendicular to the rotational axis. The lower ends of the blades 103 are fixed to the surface of the

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lower end wall 102 at its outer radial margin. The blades 103 are supported only by the lower end wall 102, which structure is called as cantilever structure. When the motor component 104 rotates in the normal direction, the blades 103 generate an airflow in the direction indicated by the arrow B_1. In the direction indicated by the arrow A_1, an intake airflow through an air inlet 108 is generated by the sucking action of this airflow B_1. On the other hand, in the direction indicated by the arrow C_1, an ejection airflow is generated by the blowing action of the airflow B_1.

[Para 0004] In configuring the impeller component 101 of conventional centrifugal fans used for electronic devices and the like, the tendency is to make the blade diameter $2r_1$ greater than the height h_1, where $2r_1$ represents the diameter of the blades 103 to their outer perimeter and h_1 represents the height of the blades 103 in the axial direction. One of the purposes of adopting this structure is to save space in the axial direction. Another purpose for thus having the blade diameter be greater than the height h_1 is to improve air volume and static pressure of the ejection airflow C_1 by raising the rotational speed at the periphery of the blades 103. Therefore, in the conventional centrifugal fan having a cantilever impeller for cooling electronic devices and the like, the impeller has a low-profile configuration in which the relationship $h_1 \leq 2r_1$ holds.

[Para 0005] In this conventional centrifugal fan, the intake airflow A_1 pushes on the airflow B_1 as indicated in Fig. 9, and the airflow B_1 strikes

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downward on the lower end wall 102 because of the shorter height h_1 of the blades, which results in a large windage loss between the downward airflow and the wall surface of the lower end wall 102. This is why, in considering the distribution of wind speed measured at several observation locations corresponding to points along the rotational axis of the impeller component 101, the wind speed of the intake airflow within the impeller tends to be maximal at the upper surface of the lower end wall 102 of the impeller. The windage loss on the wall surface can decrease airflow volume from the fan and lower the cooling efficiency below the inherent performance of the fan motor.

[Para 0006] Meanwhile, electronic devices recently are being made smaller and smaller so as to be suitable for carrying, as is the case with cellular phones, mobile personal computers, and other devices that call for being downsized further. At the same time, integration of electronic circuits has been enhanced and circuit processing speeds have been increased, which has led to a tendency for the total amount of heat produced by LSI chips and embedded electronic circuitry to increase. Therefore, there is a need to realize a fan motor having not only a smaller size but also higher cooling efficiency.

SUMMARY OF INVENTION

[Para 0007] An object of the present invention is to realize a fan motor that can be used for ultra-compact devices such as cellular phones, and that is ultrasmall in size and has high cooling efficiency, as well as to realize

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an impeller that is used for a fan motor of this sort. Another object of the present invention is to make available a fan motor capable of realizing maximum cooling efficiency with minimum air-inlet area, as well as to make available an impeller that is used for such a fan motor.

[Para 0008]

According to the present invention, a cantilever-type fan impeller comprises: a rotational force transmission portion for receiving driving force from a fan motor component; a lower endwall portion fixed in association with the rotational force transmission portion, for structuring a wall surface that is perpendicular to the impeller rotational axis; and an impeller blade unit having plural blades, disposed outer-marginally on the wall surface of the lower endwall portion and extending along rotational axis. When the fan impeller rotates, an airflow along the rotational axis, from the opening in the upper end of the impeller blade unit towards the wall surface, is generated. The relationships $2r \leq h$ and $r \leq 12.5$ mm are satisfied wherein $2r$ represents the diameter to outer circumference of the impeller blade unit and h represents the axial height of the impeller blade unit. In this fan impeller, when driving force is applied from the motor component to the rotational force transmission portion, the lower endwall portion and the impeller blade unit rotate along with the rotation force transmission portion. Then, an airflow along the rotational axis, from the opening in the upper end of the impeller blade unit towards the wall surface that is perpendicular to the axis, is

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generated. Next, the airflow hits the wall surface and changes direction. Since $2r \leq h$, windage loss at the wall surface of the lower endwall portion is reduced compared with conventional centrifugal fans, so that cooling efficiency is improved.

[Para 0009] Further according to the present invention, a fan motor having the cantilever-type impeller satisfies the relationship $k \leq$ 100 mm, wherein k represents the total axial length of the motor and the impeller. In addition, it is preferable that $k \leq$ 70 mm. This enables the fan impeller to be embedded in portable electronic devices or other small electronic devices.

[Para 0010] In another aspect of the invention, the fan motor having the cantilever-type impeller satisfies the relationship $n \geq$ 5000 rpm, more preferably, $n \geq$ 10,000 rpm, wherein n represents the rotational speed of the motor. A fan motor thus according to the present invention, having a fan impeller that is extensive along the rotational axis, can realize high static pressure and high-efficiency cooling performance when operated at the high speeds just noted.

[Para 0011] In a yet another aspect of the present invention, both the cantilever-type impeller alone or as employed in fan motors as just described may be made either entirely or partially of a liquid crystal polymer, a carbon-fiber-reinforced liquid crystal polymer, a glass-fiber-reinforced liquid crystal polymer, a carbon-fiber and glass-fiber-reinforced liquid crystal polymer, soft iron, stainless steel, aluminum, or ceramic. This contributes toward reducing the weight of and downsizing the fan

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impeller, while ensuring sufficient stiffness and airflow-generation performance in the impeller.

[Para 0012] In addition according to the invention, in a fan motor having a cantilever-type impeller, the motor component includes a rotary section and a stationary section, and a pair of axially disposed bearing units--being slide bearings or fluid dynamic pressure bearings--for rotatably supporting the rotary section against the stationary section, and the relationship $0.5m<h$ holds, wherein m represents the distance between the two axial ends of the bearing units. Having h on par with or greater than $0.5m$ contributes to keeping losses (windage losses) occurring before the airflow hits the wall surface of the lower endwall portion under control. A high-efficiency fan motor can be realized as a result. Further according to the invention, h more preferably is much greater than m. Because the length of the impeller is much longer in that case, windage losses arising before the airflow hits the wall surface of the lower endwall portion are further kept under control. A configuration thus satisfying the relationship $m<h$ suppresses windage loss on the lower endwall portion. And wherein the relationship $1.5m<h$ is satisfied, windage losses on the lower endwall portion are kept under control all the more.

[Para 0013] Still further according to the present invention, the relationship $m>h/5$ is satisfied. Increasing m to greater than $h/5$, wherein m corresponds to the so-called bearing span, makes it possible on the motor-

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component end to stabilize rotation of the cantilever-type impeller more than is the case with a fan motor configuration in which the bearing span is less than $h/5$. This contributes to improved rotational stability of the fan impeller and to minimization of losses due to vibration in the end portion of the cantilever-type impeller, so that a high-efficiency fan motor can be realized. It is further preferable according to the invention that m be larger than $h/4$, and more preferable still that m be larger than $h/3$. The bearing span is thus further increased to retain the cantilever-type impeller the more securely in rotation.

[Para 0014] A further aspect of the present invention is a fan motor having a cantilever-type impeller, wherein the motor component includes a rotary section and a stationary section, and a pair of axially separated bearing units for rotatably supporting the rotary section against the stationary section, the stationary section includes a stator, and the pair of bearing units is disposed axially sandwiching the stator. Disposing the bearing units of the pair along the motor rotational axis one on each side of the stator allows the axial bearing span to be maximized. This contributes to stabilizing impeller rotational fluctuations that are a load on the motor, so that a high efficiency fan motor with little loss due to vibrations can be realized.

[Para 0015] A still further aspect of the invention is a fan motor having a cantilever-type impeller, wherein the motor component includes a rotary section and a stationary section, and is furnished with a slide

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bearing section or a fluid-dynamic-pressure bearing section for rotatably supporting the rotary section against the stationary section; the stationary section includes a stator; and the slide bearing section or the fluid-dynamic-pressure bearing section has a structure in which each end along the rotational axis is disposed in a position axially beyond either axial end of the stator. This structure allows the bearing span along the rotational axis of the motor to be maximized. This contributes to stabilizing impeller rotational fluctuations that are a load on the motor, so that a high efficiency fan motor with little loss due to vibrations can be realized.

[Para 0016] As is evident from the comparison of structures discussed above, a fan impeller and a fan motor of the present invention have an impeller that is axially longer than conventional centrifugal fans, and the impeller is rotated at higher speed. Accordingly, windage and other losses at the wall surface of the lower endwall portion are reduced, enabling the realization of a fan motor having higher static pressure than is conventional. This makes it possible to cool high-density electronic devices and compact electronic devices with efficiency several times high than is conventional.

[Para 0017] From the following detailed description in conjunction with the accompanying drawings, the foregoing and other objects, features, aspects and advantages of the present invention will become readily apparent to those skilled in the art.

BRIEF DESCRIPTION OF DRAWINGS

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[Para 0018] Fig. 1 is a plan view of a centrifugal fan motor according to an embodiment of the present invention;

[Para 0019] Fig. 2 is a vertical cross section taken along the line X–O–Y–Z in Fig. 1;

[Para 0020] Fig. 3 is an oblique view of an impeller component of the centrifugal fan illustrated in Fig. 1, shown partially cut away as sectioned for Fig. 2;

[Para 0021] Fig. 4 is a vertical cross section of a fan motor according to another embodiment of the present invention;

[Para 0022] Fig. 5 is a graph plotting a relationship between windage loss and vibration loss;

[Para 0023] Fig. 6 is a vertical cross section of a fan motor according to still another embodiment of the present invention;

[Para 0024] Fig. 7 is a graph comparatively plotting P/Q curves for a fan motor of the present invention and for other fan motors;

[Para 0025] Fig. 8 is a plan view of a conventional centrifugal fan motor; and

[Para 0026] Fig. 9 is a vertical cross section taken along the line X_1–O_1–Y_1–Z_1 in Fig. 8.

DETAILED DESCRIPTION

[Para 0027]

Reference is made to Fig. 1, which is a plan view of a centrifugal fan motor according to an embodiment of the present invention, and to

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Fig. 2, which is a vertical cross section, taken along the line X–O–Y–Z in Fig. 1. The vertical direction in Fig. 2 corresponds to the orientation of the rotational axis of the centrifugal fan motor. Though upper and lower sides are defined according to Fig. 2 in the following explanation, the definitions are for convenience of explanation and are not meant to imply restrictions on the actual attachment posture of the fan motor.

[Para 0028] This fan motor includes an impeller component 1, a motor component 4 and a housing 6. The impeller component 1 and the motor component 4 are disposed axially stacked and connected to each other, and these interconnected components are contained in the housing 6. The rotational axis of this centrifugal fan motor is indicated by *O* in Fig. 1.

[Para 0029] Reference is now made to Fig. 3, which shows the impeller component 1 in a partially cut away oblique view as sectioned for Fig. 2. As will be understood from Fig. 3, the impeller component 1 is an impeller of the cantilever type used for centrifugal fan motors. The impeller component 1 includes a rotational force transmission portion 5 for receiving drive force from the motor component 4, a lower endwall portion 2 fixed thereto, and an impeller blade unit 3 having plural blades, each of the blades being fixed at its lower end to the outer margin of the wall surface of the lower endwall portion 2 and each extending along the rotational axis to its upper end. Each blade of the impeller blade unit 3 is cantilevered, that is, the lower end

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thereof is fixed to the lower endwall portion 2 while the upper end thereof is not supported by anything. In other words, the "lower end" of the impeller blade unit 3 means a fixed end while the "upper end" of the same means a free end. An opening 9 that is a circular space is defined by the upper ends of the plural blades of the impeller blade unit 3. When the impeller component 1 rotates, an airflow is generated streaming along the rotational axis through the opening 9 in the upper end of the impeller blade unit 3 and towards the upper surface of the lower endwall portion 2. The lower endwall portion 2 is a disk-like member having a surface that faces the rotational axis in this embodiment. The upper surface of the lower endwall portion 2 forms a lower wall surface of the impeller blade unit 3 and functions to stop the airflow along the axial direction. As shown in Fig. 2, the upper rim portion of the impeller blade unit 3 is fitted with a ring connection portion 10 holding the blades together for reinforcement. The housing 6 encompasses the circumference of the impeller component 1 and the circumference of the lower end of the motor component 4. In the upper portion of the housing 6 is an air inlet 6a, and in the side portion thereof is an air outlet 6b. In addition, the base of the motor component 4 is fixed to or formed integrally with the upper surface of the bottom of the housing 6.

[Para 0030]

The rotational force transmission portion 5 is connected to a rotor of the motor component 4, and the plural blades of the impeller blade unit 3 extending along the axial direction generate an airflow *B* in

response to rotation of the motor, thereby realizing a blowing function. This airflow *B* induces an intake airflow *A* through the air inlet 6a of the housing 6 and the impeller opening 9, and consequently airflows *A*, *B* and *C* are generated, whereby the airflow C is directed from the air outlet 6b of the housing 6 onto a cooling target (not illustrated).

[Para 0031] In the centrifugal fan motor according to this aspect of the present invention, compared with the conventional centrifugal fan motor represented in Fig. 8, the diameter $2r$ of the impeller blade unit 3 to its outer circumference is less than the height h of the impeller component 1 (that is, the length of the impeller blade unit 3 along the axial direction that can generate the ejection airflow; more specifically, the distance along the axial direction between the upper surface of the lower endwall portion 2 and the undersurface of the ring connection portion 10). In addition, the fan motor according to this aspect of the invention can cool a portable electronic device or a compact device efficiently at high static pressure, while the motor configuration satisfies the relationship $r \leq 12.5$ mm.

[Para 0032] If the height h of the impeller component 1 in the axis direction is greater than the diameter $2r$ of the impeller blade unit 3 to its outer circumference, the intake airflow *A* generated by the rotational airflow *B* along the circumference direction by the impeller blade unit 3 transitions to the airflow *B* smoothly before reaching the lower endwall portion 2 of the impeller component 1, reducing the wind speed at the upper surface of the lower endwall portion 2.

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[Para 0033] In terms of the distribution of airflow speed along the rotational axis of the impeller component 1, as *h* becomes taller, the point of maximum speed in the airflow as observed at several locations corresponding to points along the axis should move to a point inside the impeller, with the airflow speed at the upper surface of the lower endwall portion 2 decreasing from that of the conventional centrifugal fan. As a result, windage loss on the upper surface of the lower endwall portion 2 can be expected to decrease. Here, the observation point along the axis of the impeller component 1 that is the maximum wind-speed point in the airflow speed distribution should be noted.

[Para 0034] In a conventional centrifugal fan for cooling an electronic device, the maximum wind-speed point among observation points along the axis should not appear at a point inside the impeller; instead, the airflow speed should be maximum on the upper surface of the lower endwall portion 2. In contrast, if the following relationship *(1)* between the diameter 2*r* to the outer circumference of the impeller blade unit 3, and the height *h* of the impeller component 1, is satisfied and the rotation speed of the fan is 5000 rpm or higher, the maximum wind-speed point along the axis should appear inside the impeller, so that the airflow-speed maximum will no longer be on the upper surface of the lower endwall portion 2.

$$2r \leq h \qquad (1)$$

[Para 0035] As a result, compared with the conventional centrifugal fan, the windage loss on the upper surface of the lower endwall portion 2 is

reduced. Thus, a fan having high static pressure and high cooling efficiency compared with conventional centrifugal fans can be realized. In particular, a fan in which the relationship $r \leq 12.5$ mm is satisfied will realize high cooling efficiency.

[Para 0036] One of the factors related to whether or not the maximum wind-speed point along the axis appears inside the impeller--and to where it appears along the axis inside the impeller--is the shape of the impeller component. The present invention definitively sets forth that if the relationship defined by the following expressions *(2)* and *(3)* using a parameter α is satisfied between the area of intake airflow into the impeller component 1 (that is, the area of the cross section perpendicular to the axis at the upper-end portion of the impeller component, i.e., πr^2), and the area of ejection airflow of air blown by th impeller blade unit 3 (that is, the effective cylindrical area of the impelle blade unit 3 of the impeller component that contributes to blowing of th airflow, i.e., $2\pi rh$), the airflow speed maximum will not be on the upper surface of the lower endwall portion 2, whereby the impeller produces efficient airflow.

$$2\pi rh = \alpha\pi r^2 \qquad (2)$$

$$4 \leq \alpha \leq 40 \qquad (3)$$

[Para 0037] Thus, a fan motor having a smaller windage loss and higher efficiency than conventional centrifugal fans can be realized.

[Para 0038] Though the airflow speed maximum should not appear on the upper

surface of the lower endwall portion 2 even if $\alpha > 40$, cantilever-type impellers prove to be over-extensive axially the as α becomes larger than that, making it is difficult to obtain stable impeller rotation, and as a result loss due to impeller vibration or other factors may increase, and the cooling efficiency of the fan may decrease.

[Para 0039] In certain practical applications, it is more preferable that the following relationship *(4)* is satisfied.

$$5 \leq \alpha \leq 35 \qquad (4)$$

[Para 0040] If $5 \leq \alpha$, the maximum wind-speed point should appear along the axis inside the impeller and at a position relatively distant from the lower endwall portion 2, producing a correspondingly sufficient drop in the airflow speed at the upper surface of the lower endwall portion 2. Therefore, the windage loss at the upper surface of the lower endwall portion 2 can be reduced further so that a centrifugal fan having higher efficiency can be realized.

[Para 0041] Since $\alpha \leq 35$ on the other end of the range, the impeller is not over-extensive axially, so that stable rotation of cantilever-type impellers can be realized. Thus, impeller vibration is further reduced, so that a fan motor having better cooling efficiency can be realized.

[Para 0042] The above-explained comparison between the intake airflow area of th impeller component 1 and the ejection airflow area of the air blown by the impeller blade unit 3 can be applied to the case where the circular area of the impeller $2\pi rh$ is large enough relative to the total sum dhZ

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(where Z is the number of blades in the impeller blade unit) of the area of the cylindrical cross sections dh (where d is the blade thickness) around the axis of the impeller blade unit 3 that the latter can be neglected. However, if the diameter $2r$ to the outer circumference of the impeller blade unit is reduced such that the total sum of the area of the cylindrical cross sections of the impeller blade unit 3 cannot be neglected, a gap ratio ε defined by the following equation *(5)* must be taken into consideration.

$$\varepsilon = (2\pi r - Zd)/2\pi r \qquad (5)$$

[Para 0043] In this case of the present invention, the ejection airflow effective area of the air blown by the impeller blade unit 3 becomes $2\pi r\varepsilon h$. Here it is definitively set forth that if the relationship defined by the following expressions *(6)* and *(7)* using a parameter β is satisfied, the airflow speed will not have the maximum value on the upper surface of the lower endwall portion 2, so that higher cooling efficiency with higher static pressure can be obtained.

$$2\pi r\varepsilon h = \beta\pi r^2 \qquad (6)$$

$$3 \le \beta \le 30 \qquad (7)$$

[Para 0044] Thus, a fan motor having a smaller windage loss and higher efficiency than the conventional centrifugal fan can be realized.

[Para 0045]

The reason for $3 \le \beta$ is that if β has a value less than three, the airflow speed maximum may be at the upper surface of the lower endwall

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portion 2, and a windage loss similar to conventional centrifugal fans may be produced at the upper surface of the lower endwall portion 2, leading to decreased cooling efficiency of the fan. On the other hand, the reason why $\beta \leq 30$ is that if β has a value greater than 30, the impeller may become axially over-extensive in accordance with the larger value of β, making it difficult to obtain stable rotation of a cantilever-type impeller, even though the airflow speed does not have its maximum value on the upper surface of the lower endwall portion 2. In certain practical applications, the value of β thus is preferably 30 or smaller.

OTHER EMBODIMENTS

[Para 0046]

Next, another embodiment demonstrating further effects of the present invention will be explained with reference to Fig. 4. Fig. 4 shows a cross section, taken along a plane including the rotational axis, of a fan motor, and in the fan motor the impeller component 1 and the motor component 4 are structured integrally. For the most part, the fan motor has a structure similar to that shown in Fig. 2, and to refer to elements having the same function the same reference numerals are also used in Fig. 4. The horizontal direction in Fig. 4 corresponds to the rotational axis direction of a centrifugal fan motor. Though the right side in Fig. 4 is referred to as the "upper side" and the left side in Fig. 4 is referred to as the "lower side" in the following explanation, these references are for convenience of explanation and are not meant to imply restrictions on the actual attachment posture of

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the fan motor.

[Para 0047] This fan motor includes an impeller component 1 and a motor component 4. The impeller component 1 and the motor component 4 are disposed axially stacked and connected to each other.

[Para 0048] The impeller component 1 is an impeller of the cantilever type used for centrifugal fan motors. The impeller component 1 includes: a drive force transmission portion 11 for receiving drive force from the motor component 4; a rotor-side lower endwall portion 2, fixed to the transmission portion 11, and a stationary-side lower endwall portion 12; and an impeller blade unit 3 having plural blades, each of the blades being fixed at its lower end to the outer margin of the wall surface of the lower endwall portion 2 and each extending along the rotational axis to its upper end. The impeller blade unit 3 is cantilevered, that is, the lower end thereof is fixed to the lower endwall portion 2 while the upper end thereof is not supported by anything. When the impeller component 1 rotates, an airflow is generated streaming along the rotational axis through the opening 9 in the upper end of the impeller blade unit 3 and towards the upper surface of the lower endwall portions 2 and 12. The lower endwall portion 2 is an annular section belonging to the rotor side, while the lower endwall portion 12 is a disk-like section disposed inside the lower endwall portion 2 and belonging to the stationary side. Thus, the two together constitute a disk-like shape. The impeller component 1 further includes a ring connection portion 10 for linking the blades of